

US006768155B2

(12) **United States Patent**
JaiPrakash et al.

(10) **Patent No.:** **US 6,768,155 B2**
(45) **Date of Patent:** **Jul. 27, 2004**

(54) **CIRCUIT WITH BURIED STRAP INCLUDING LINER**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

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(21) Appl. No.: **10/438,352**

(22) Filed: **May 14, 2003**

(65) **Prior Publication Data**

US 2004/0000683 A1 Jan. 1, 2004

Related U.S. Application Data

(62) Division of application No. 10/186,043, filed on Jun. 28, 2002, now Pat. No. 6,605,504.

(51) **Int. Cl.**⁷ **H01L 29/76**; H01L 29/94; H01L 31/062; H01L 31/113; H01L 31/119

(52) **U.S. Cl.** **257/301**; 257/302; 257/303; 257/304; 257/305

(58) **Field of Search** 257/301-306

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(57) **ABSTRACT**

Semiconductor devices having trenches with buried straps therein preventing lateral out-diffusion of dopant are provided along with methods of fabricating such semiconductor devices.

15 Claims, 18 Drawing Sheets

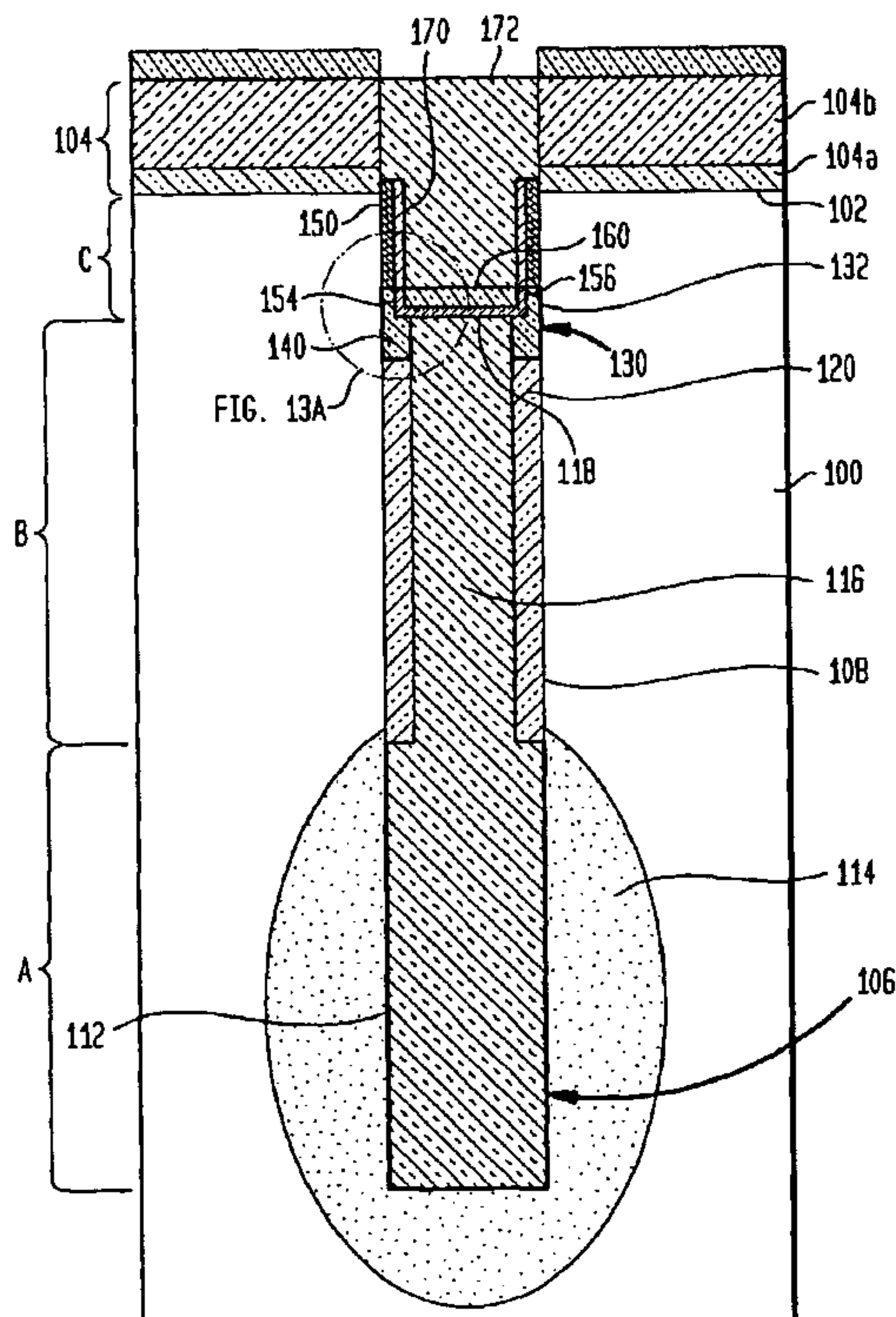


FIG. 1

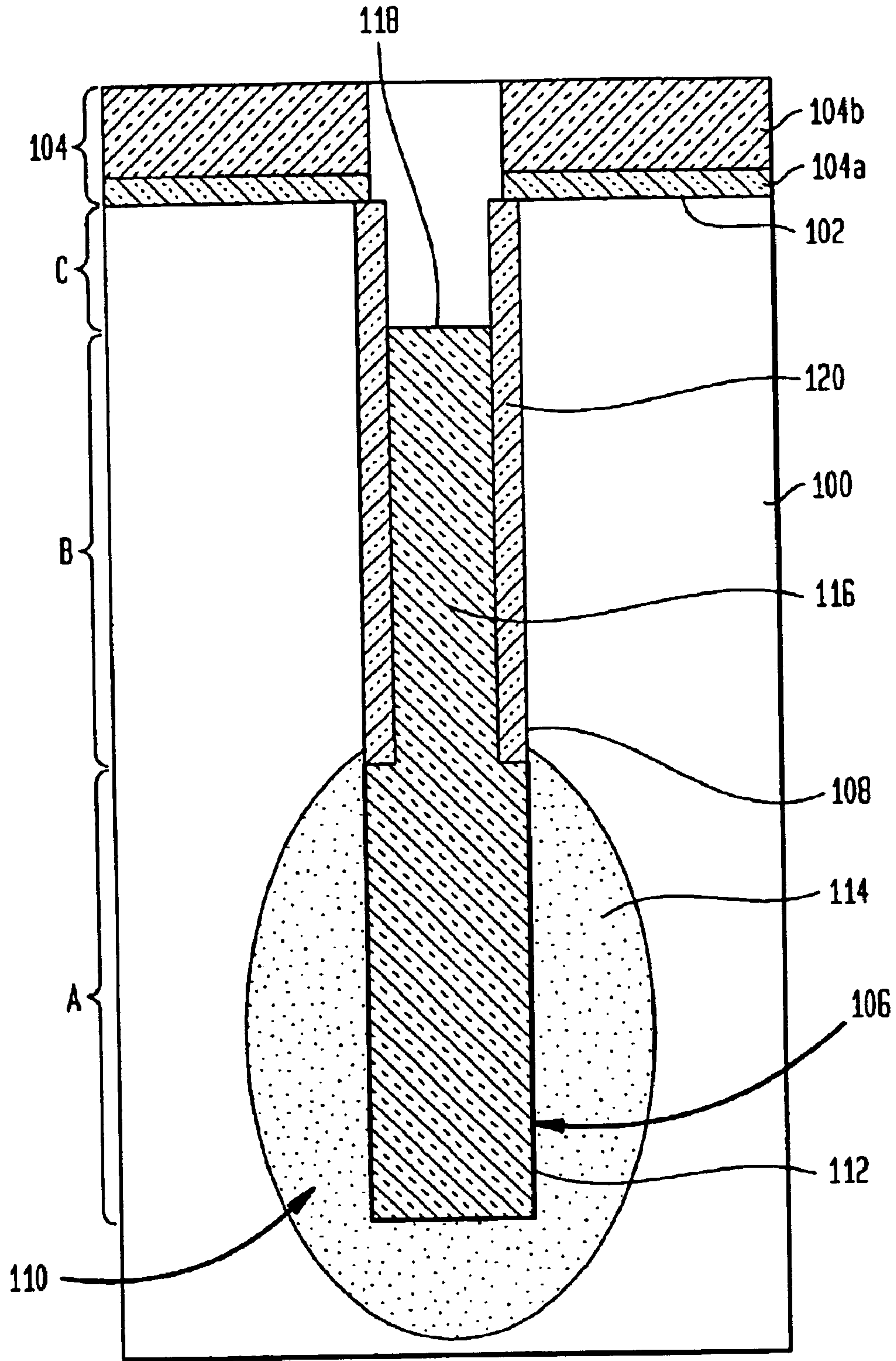


FIG. 2A

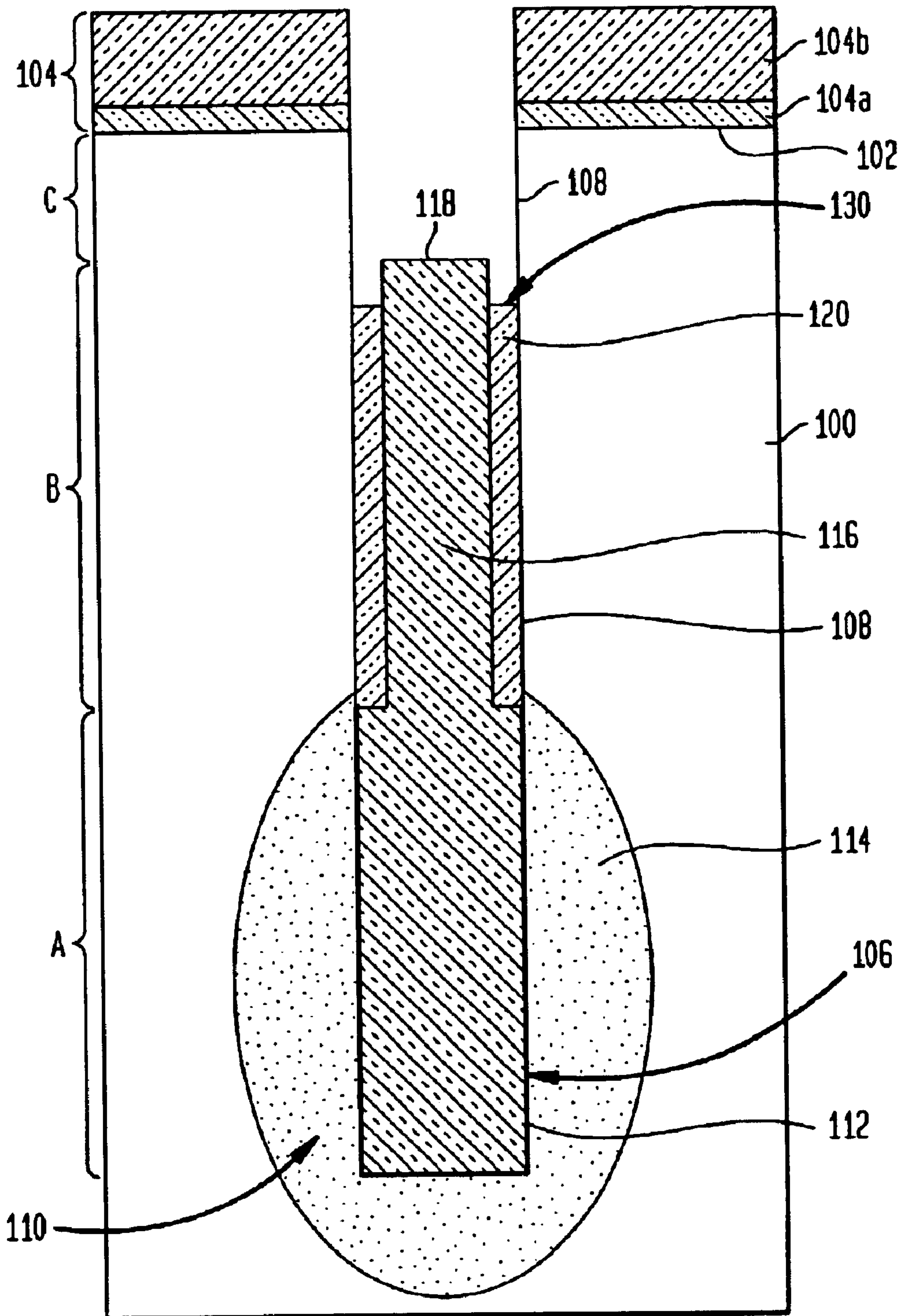


FIG. 3

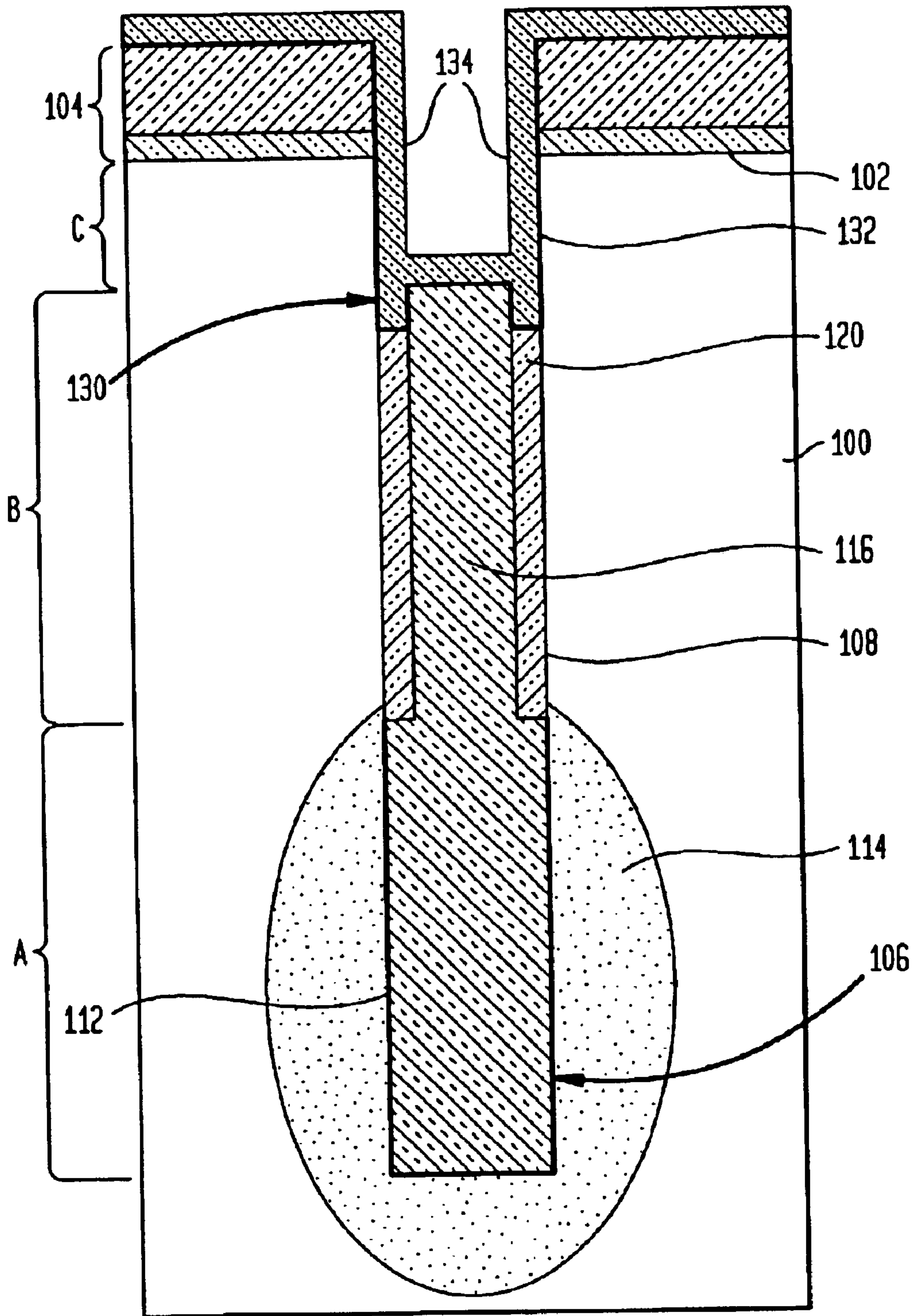


FIG. 4A

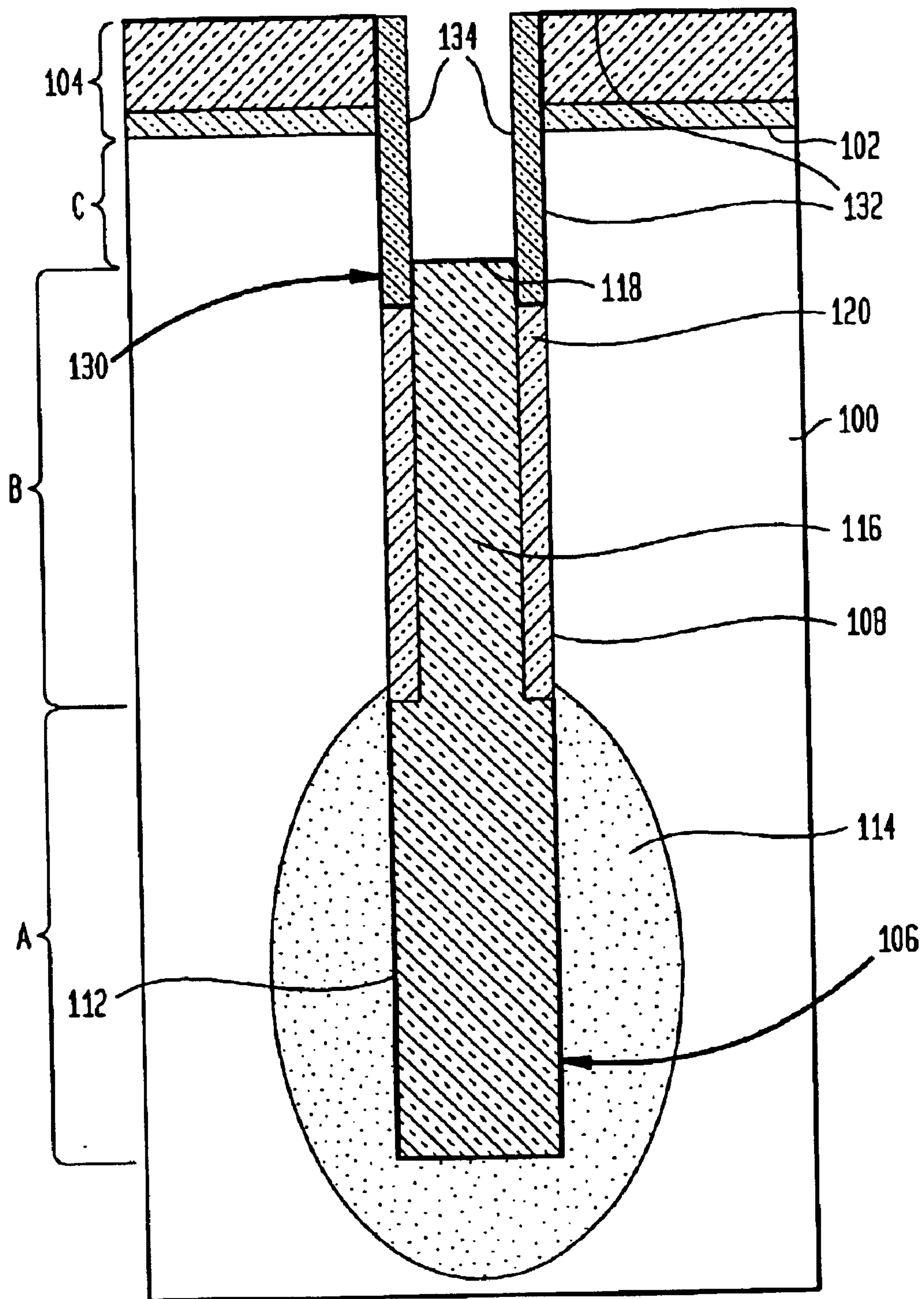


FIG. 4D

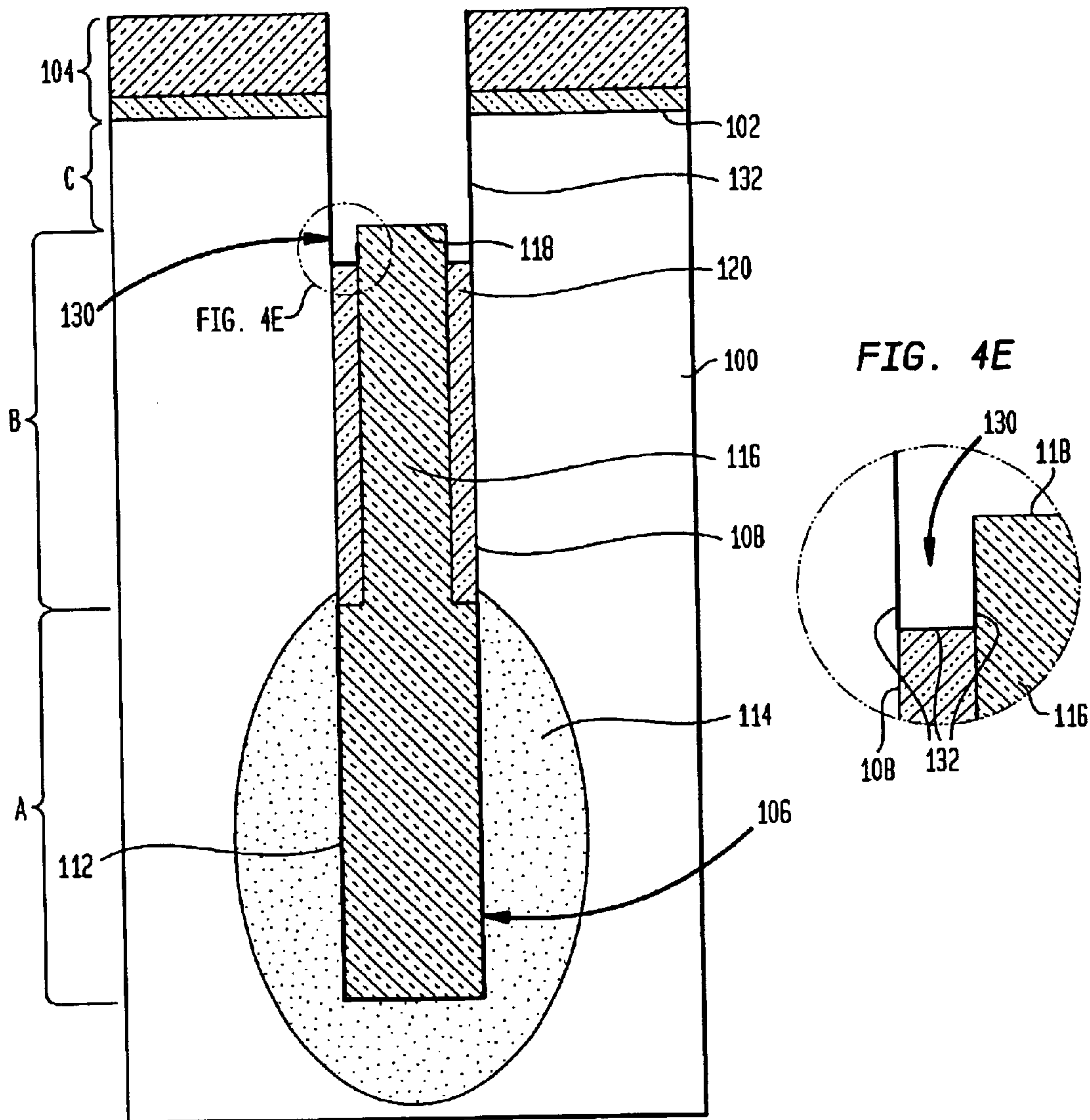


FIG. 5A

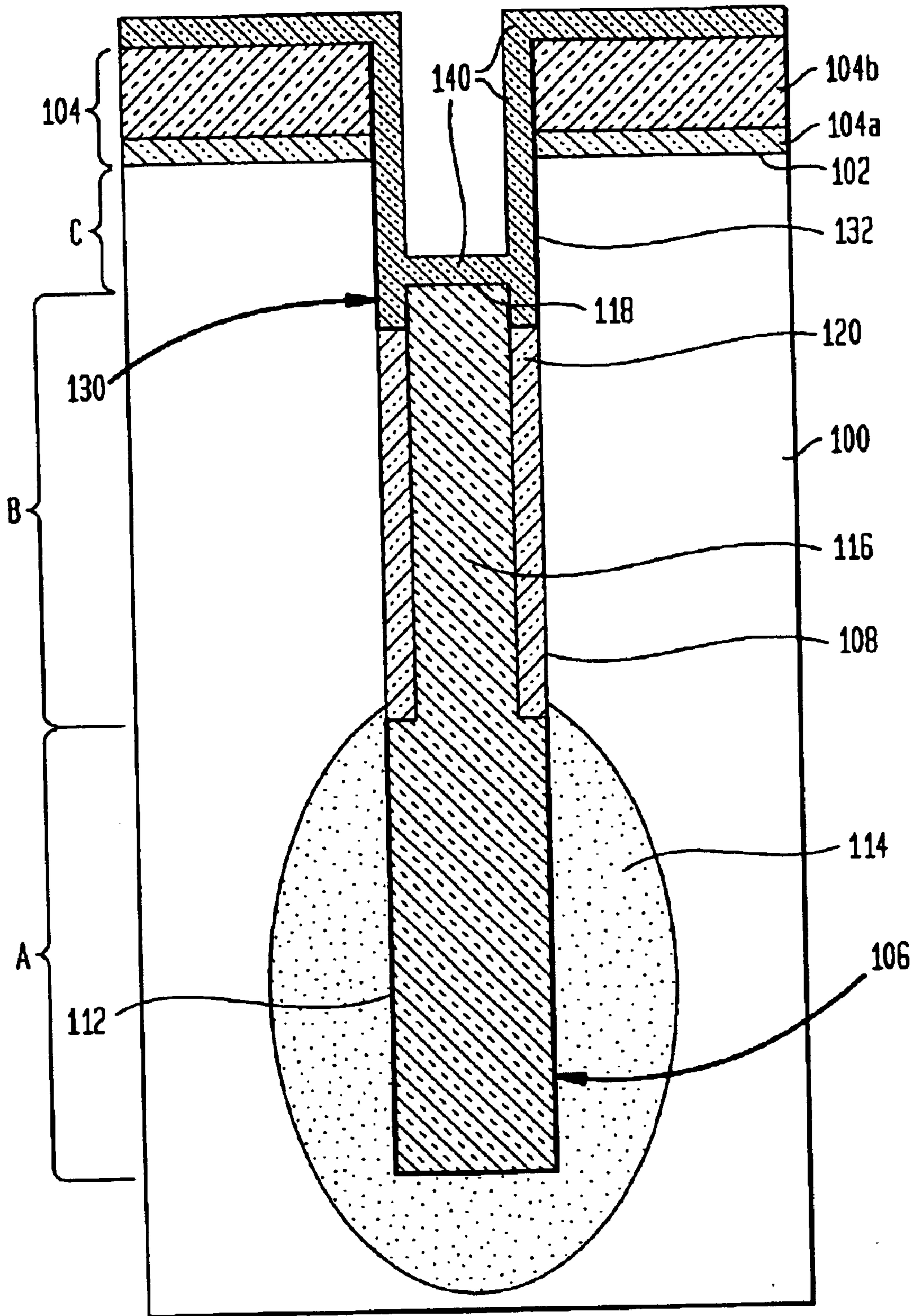
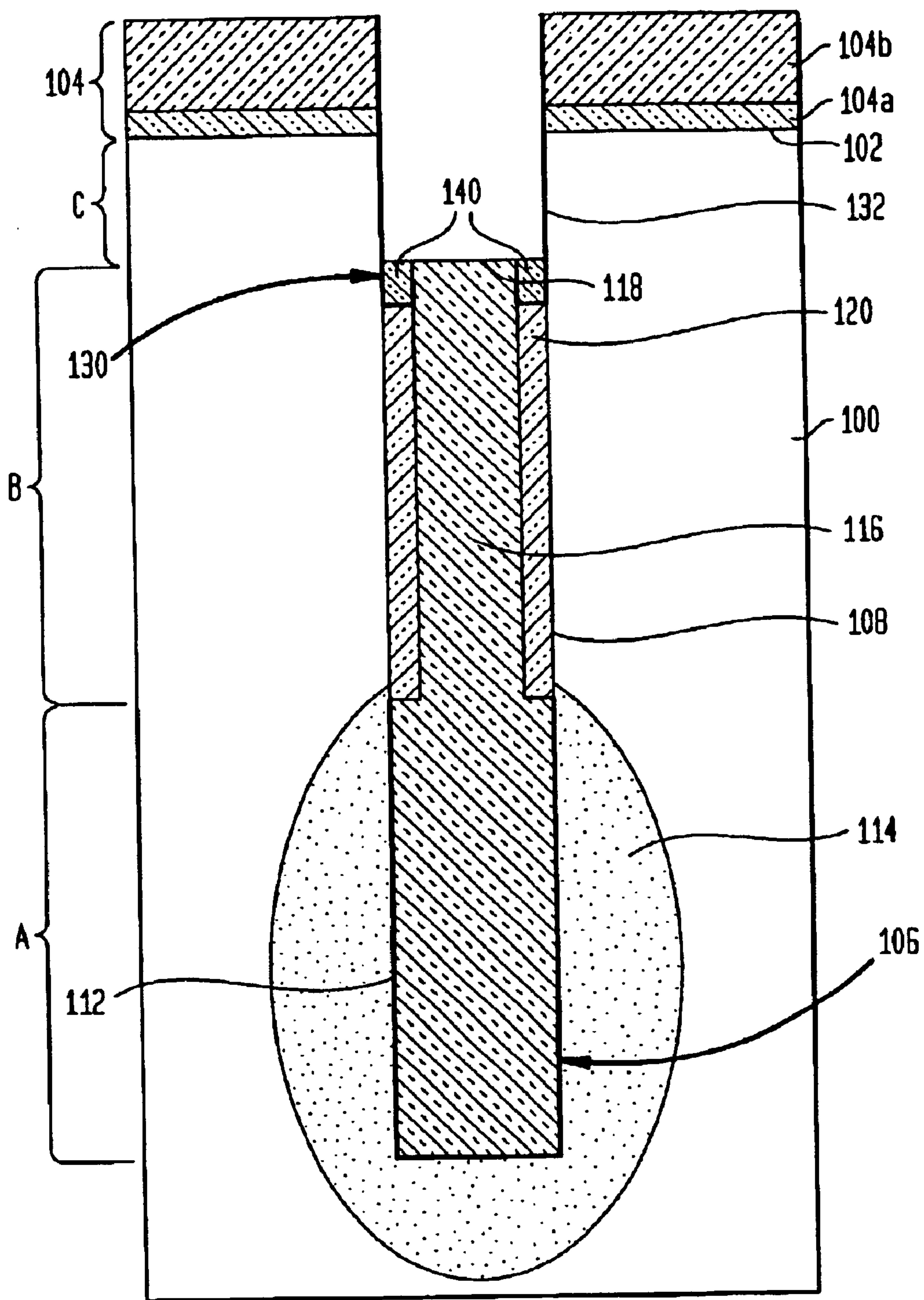


FIG. 5B



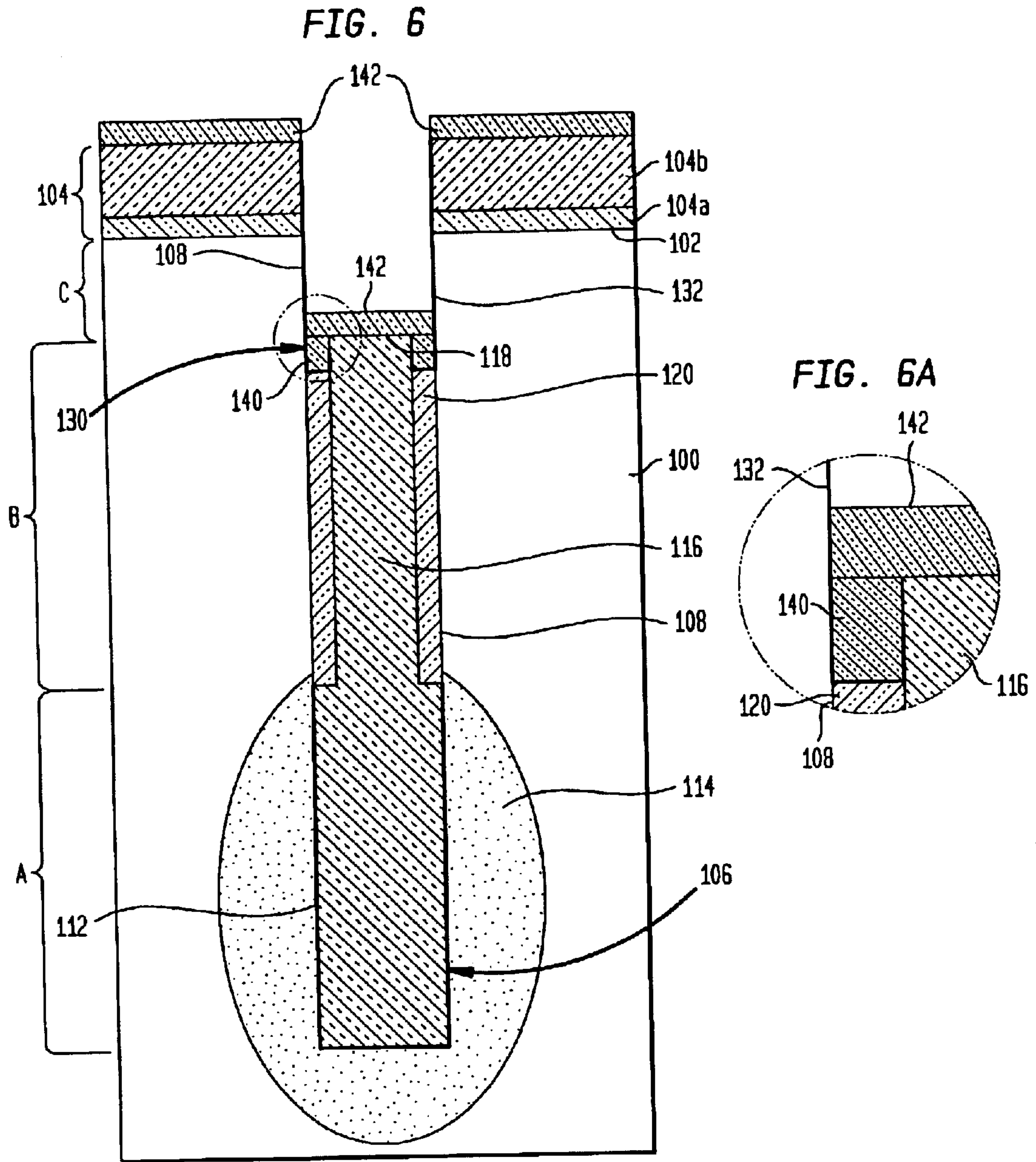


FIG. 7

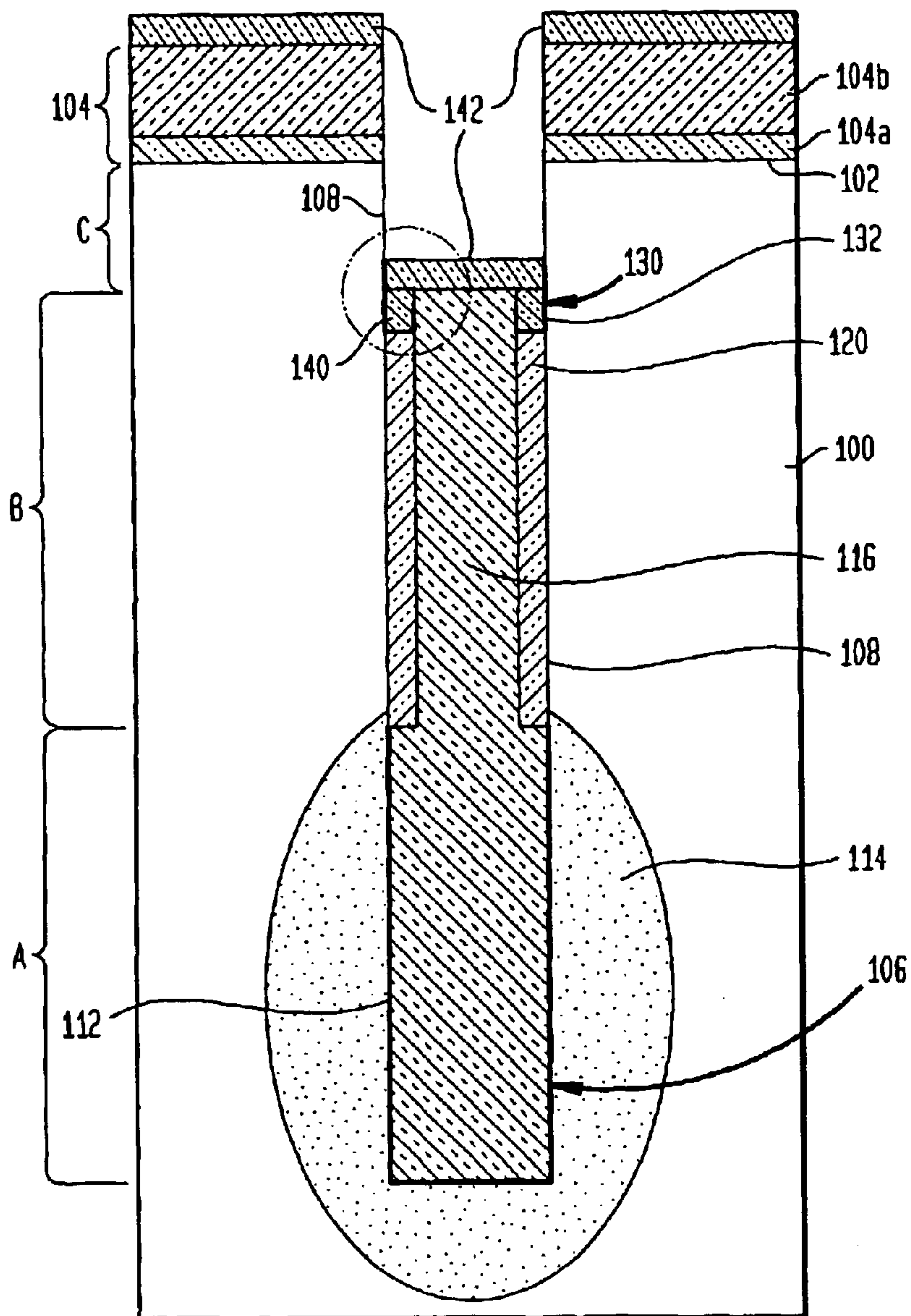


FIG. 7A

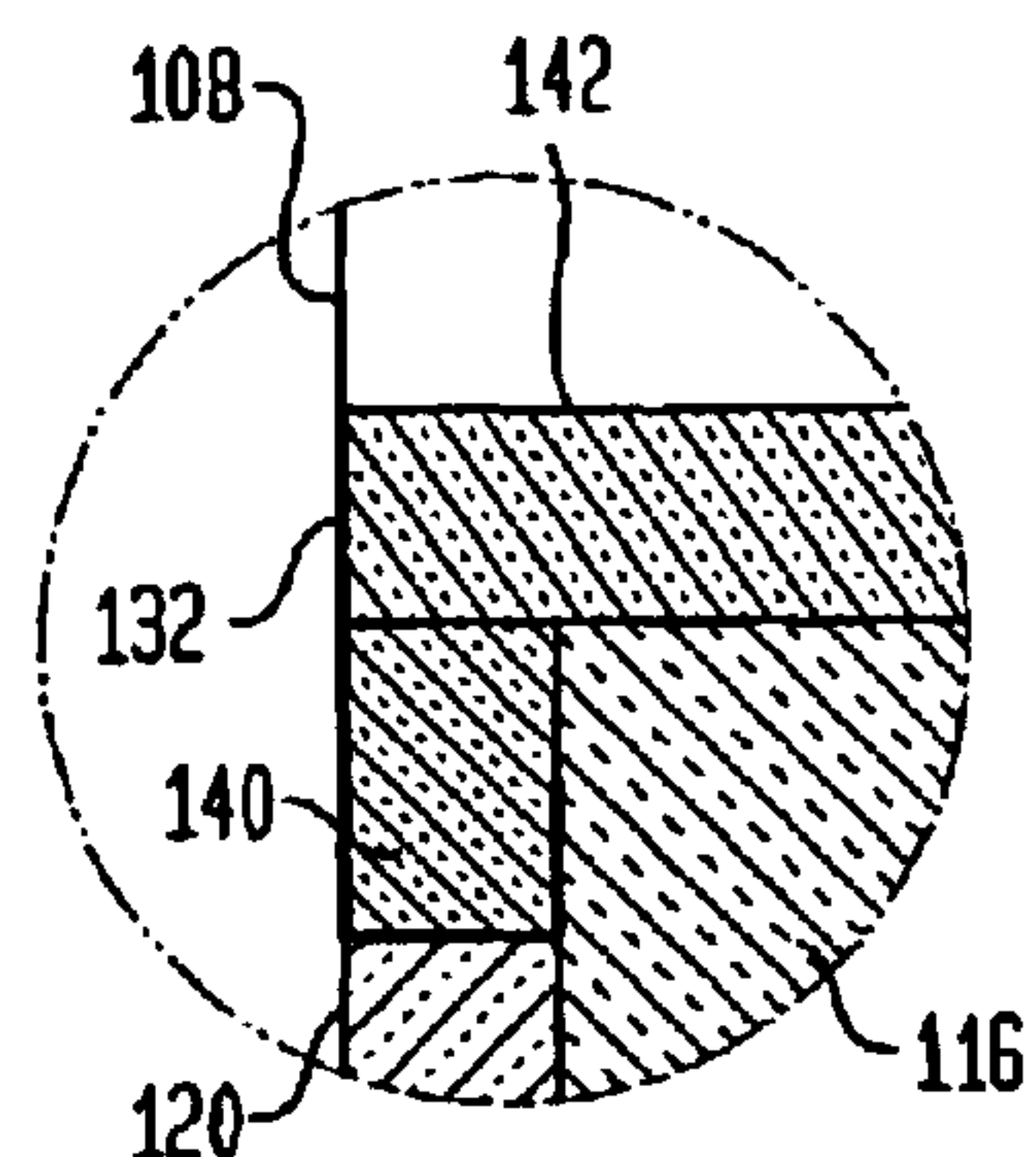


FIG. 8

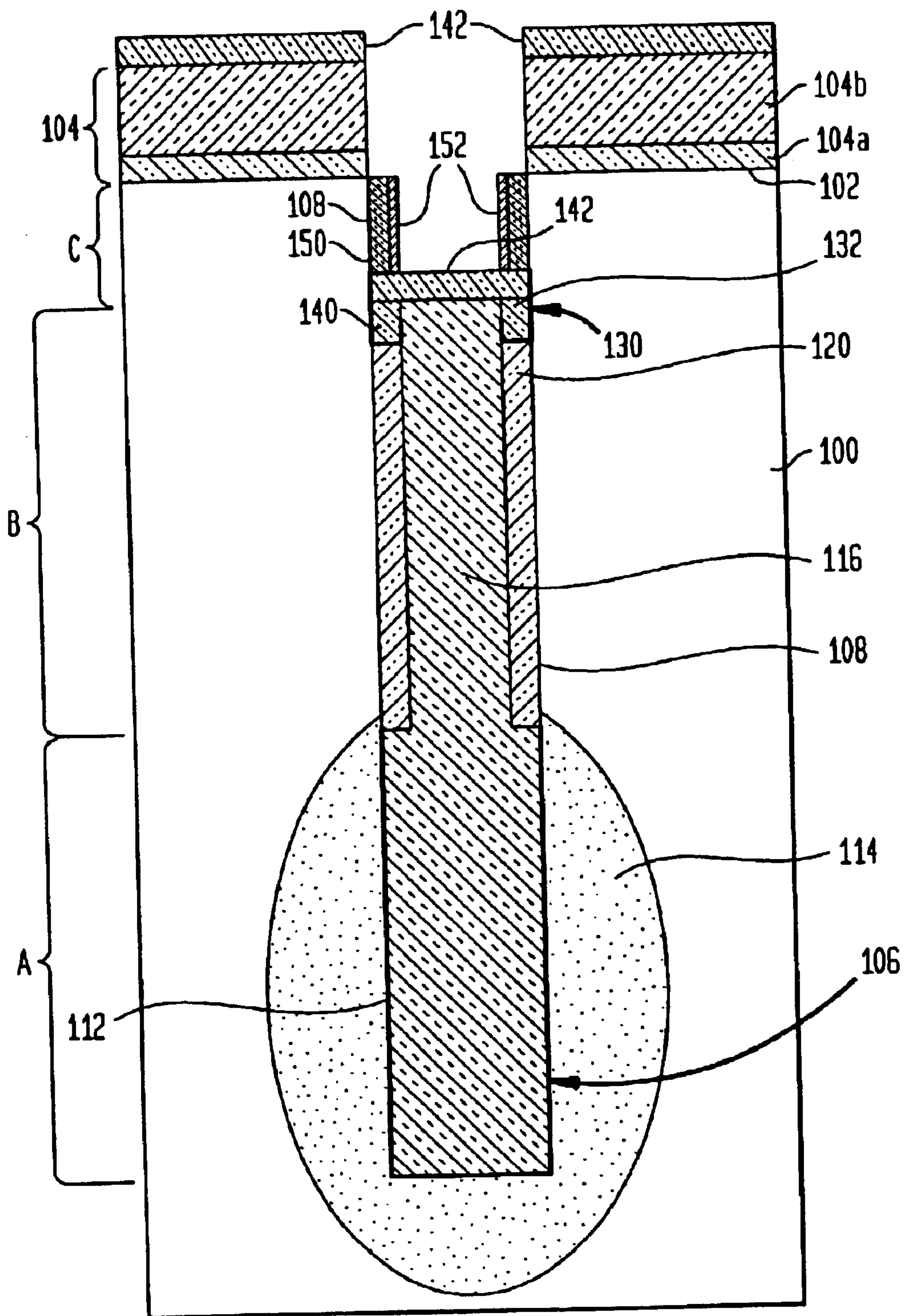


FIG. 9

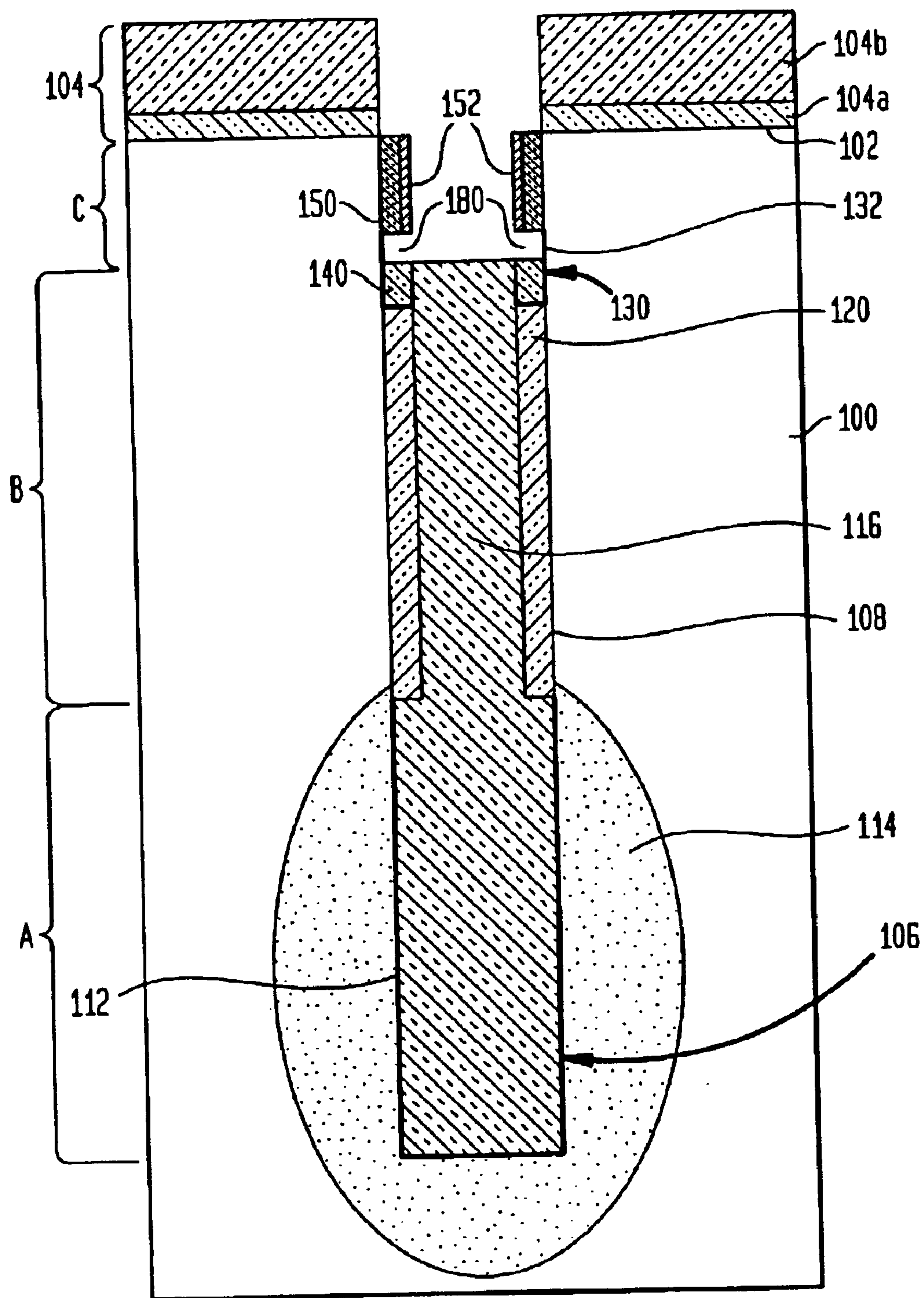


FIG. 10A

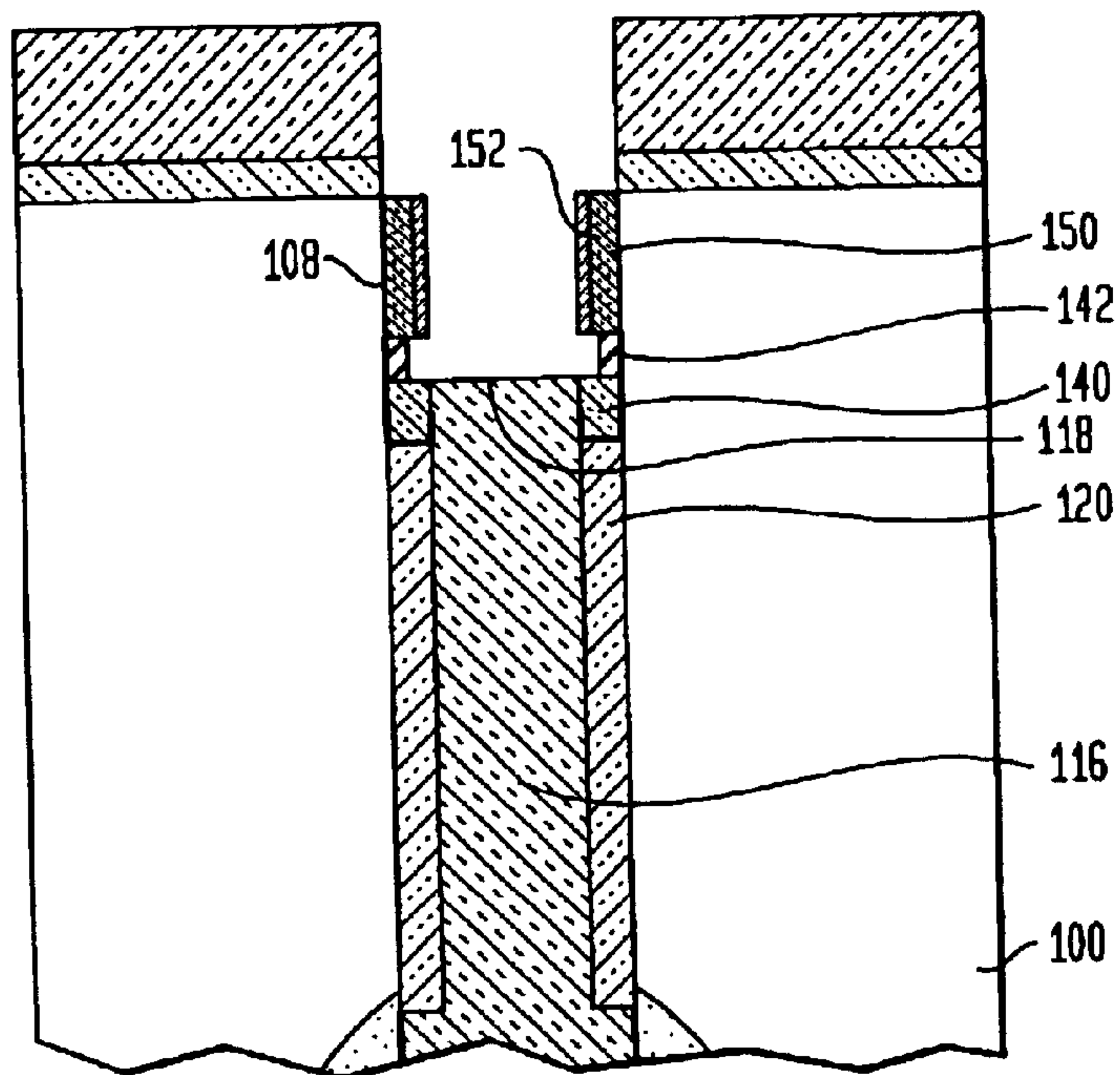


FIG. 10B

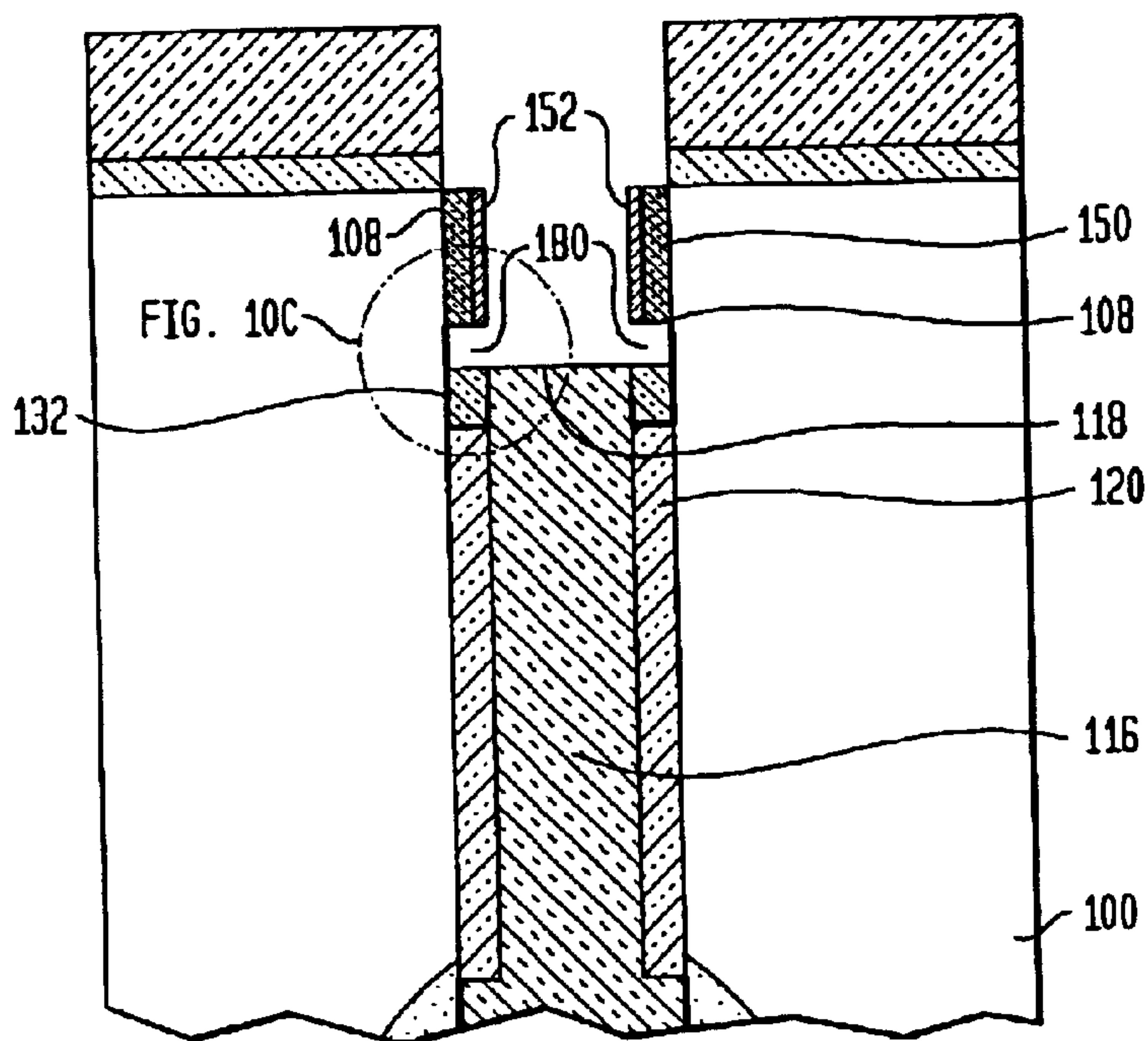


FIG. 10C

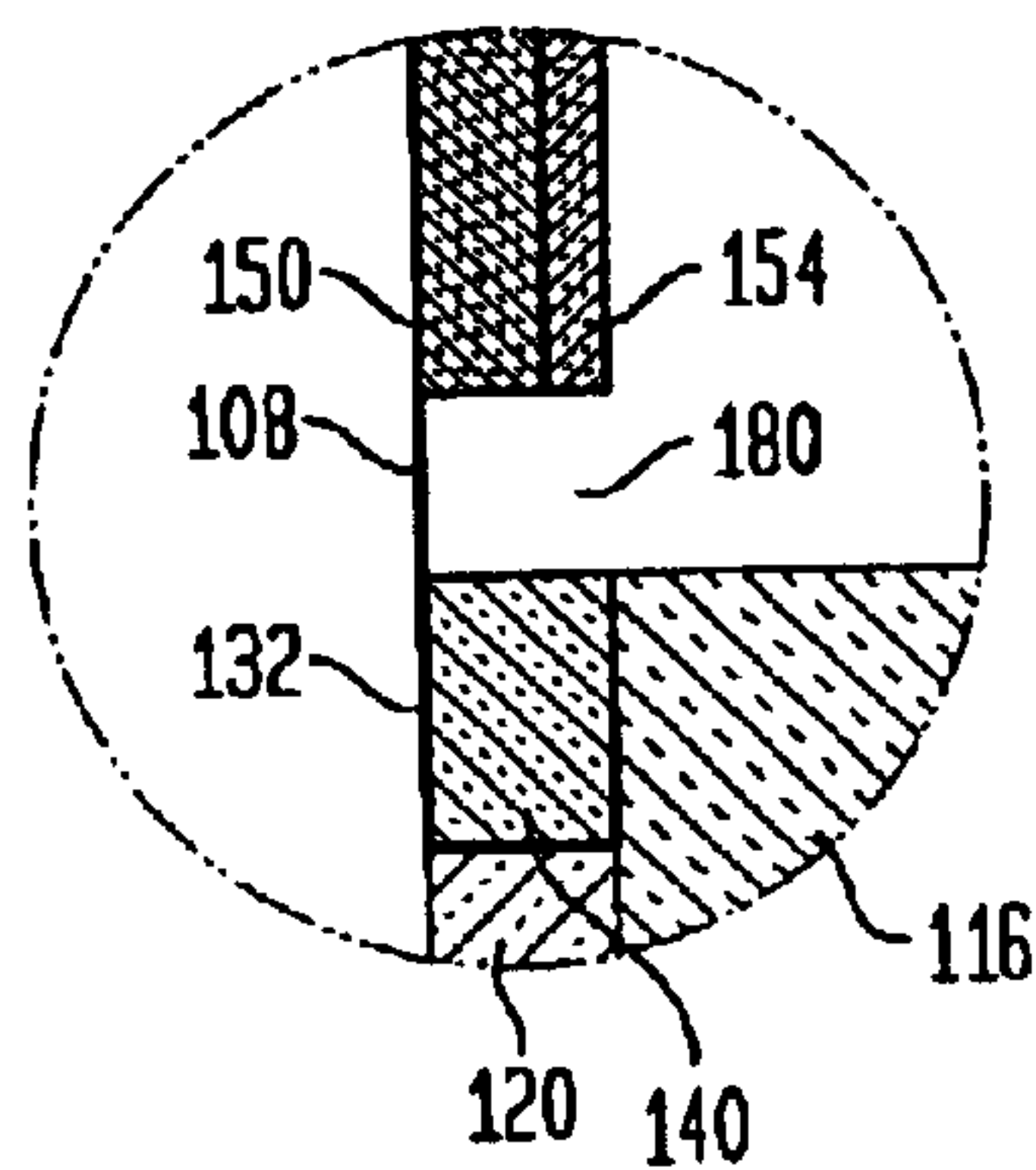


FIG. 11A

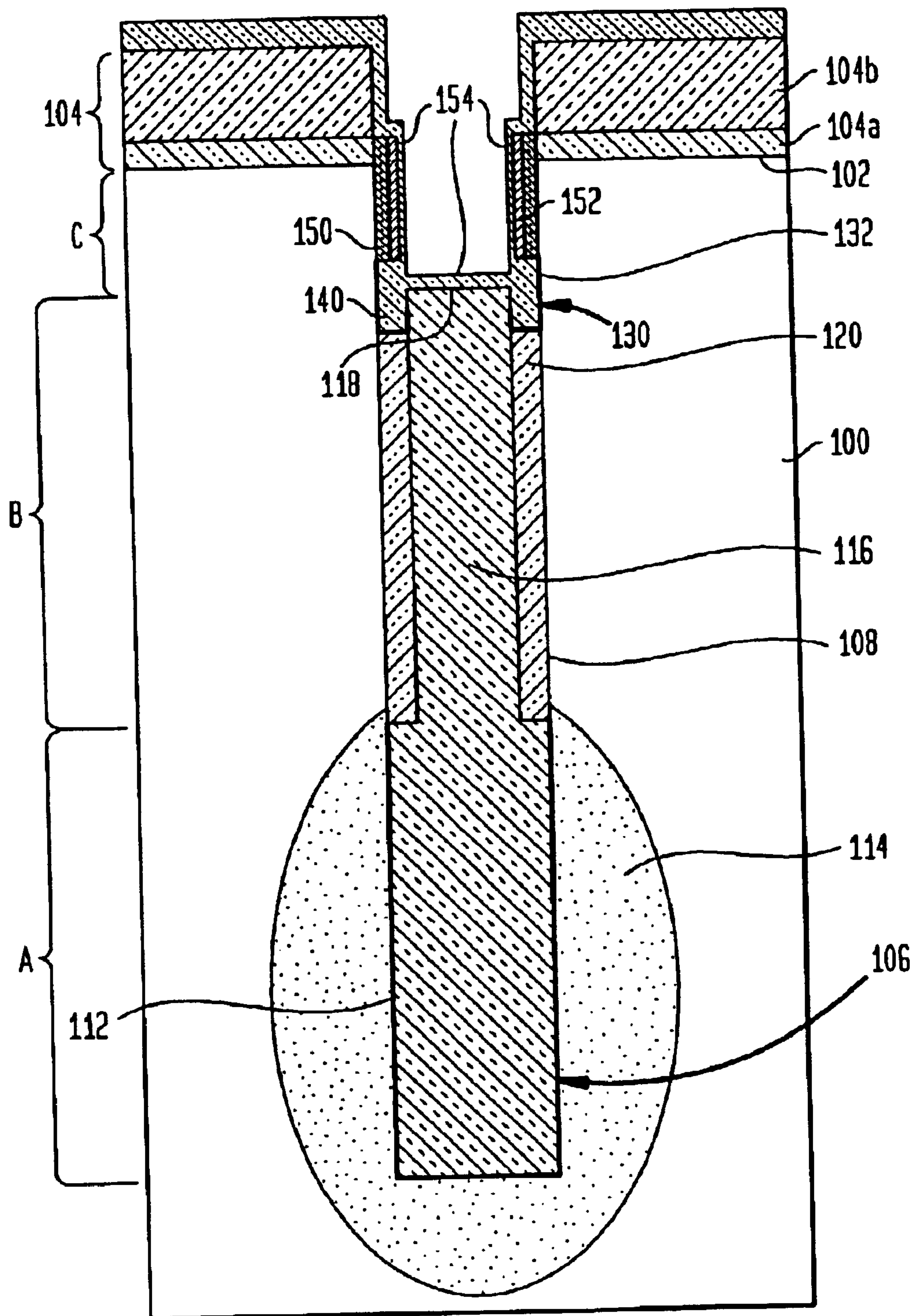


FIG. 11B

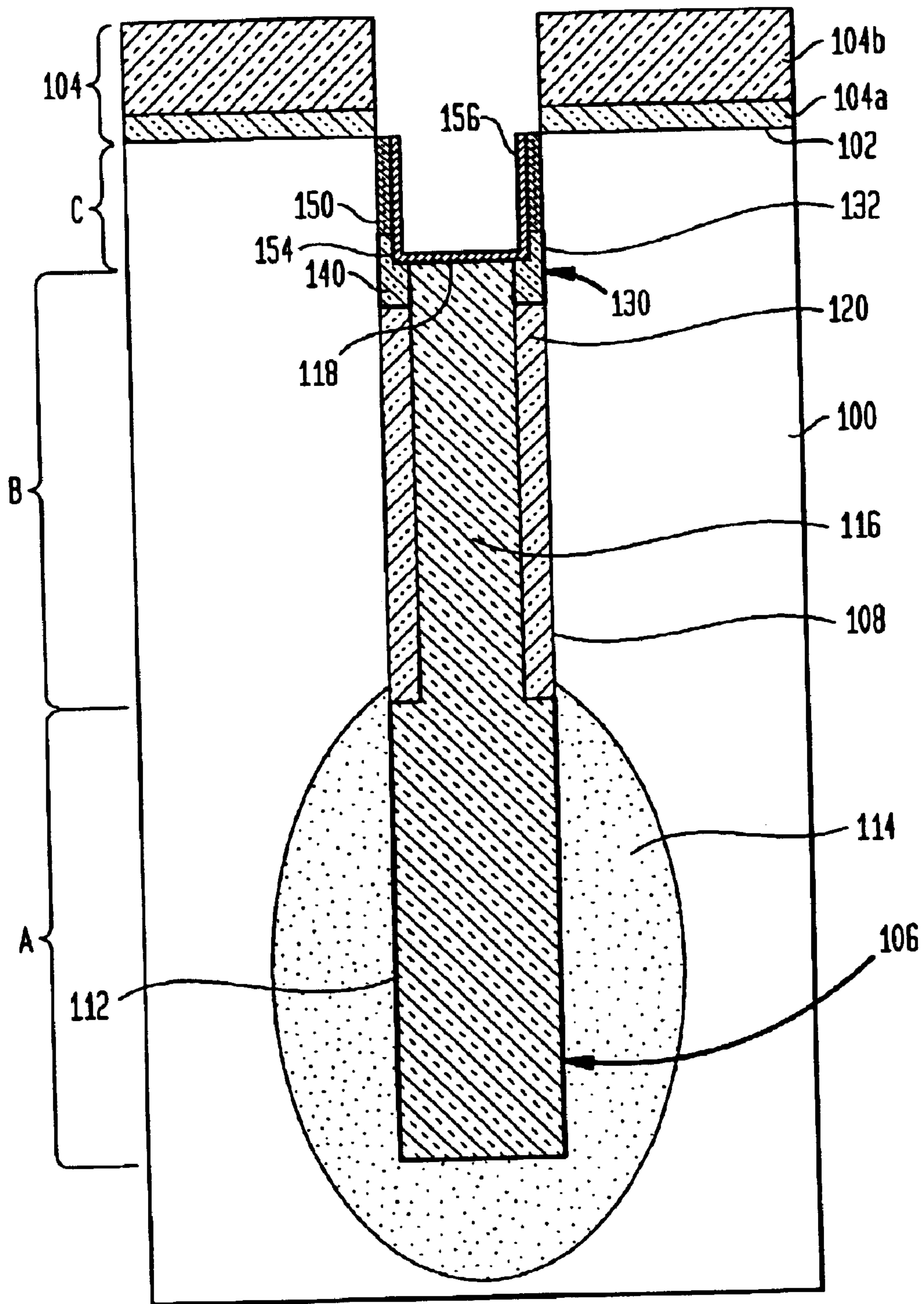


FIG. 12

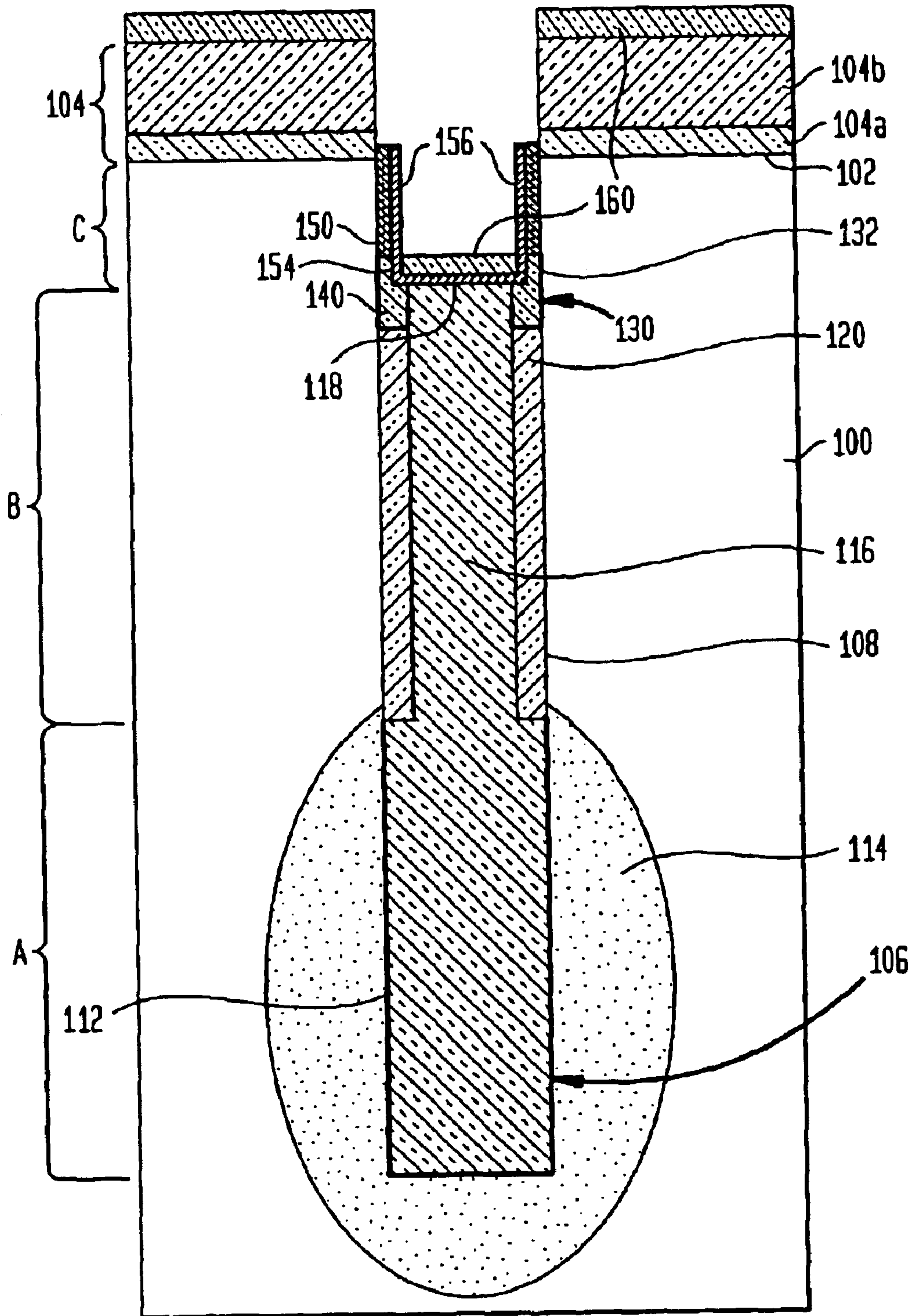


FIG. 13

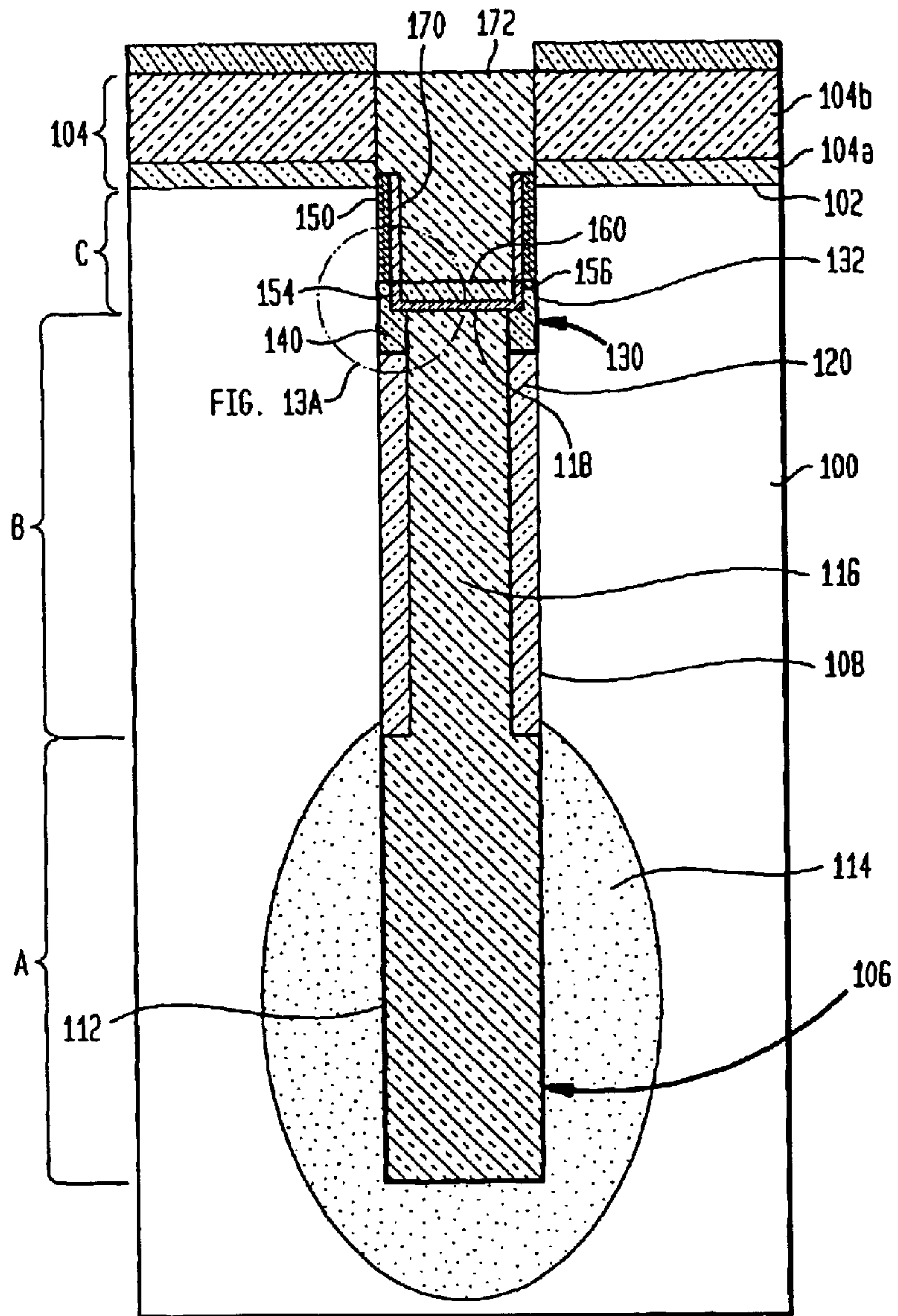
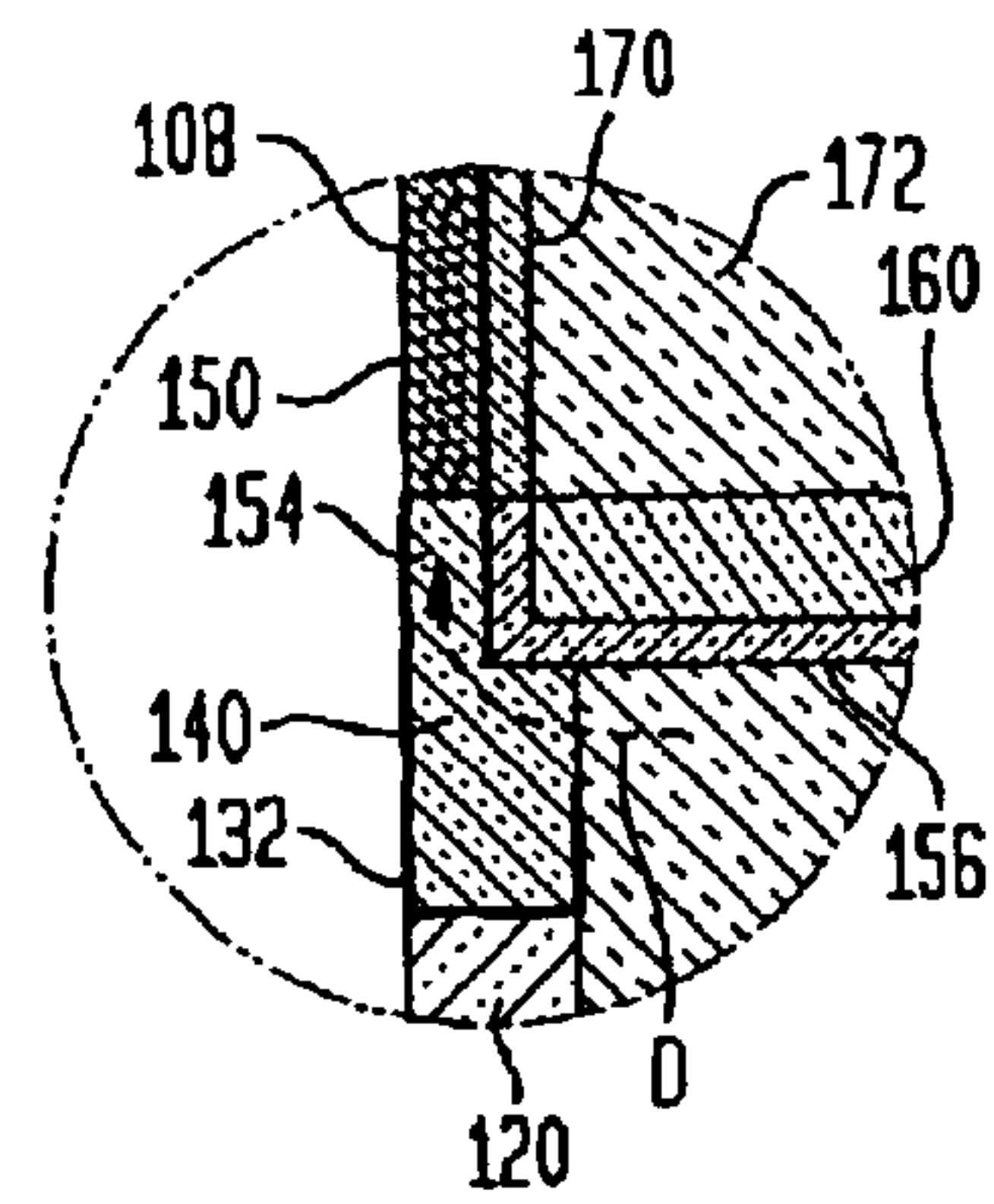


FIG. 13A



CIRCUIT WITH BURIED STRAP INCLUDING LINER

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a divisional application of U.S. patent application Ser. No. 10/186,043, filed Jun. 28, 2002, entitled METHOD OF MANUFACTURING CIRCUIT WITH BURIED STRAP INCLUDING LINER, now U.S. Pat. No. 6,605,504, issued Aug. 12, 2003, the entire disclosure of which is hereby expressly incorporated by reference.

BACKGROUND OF THE INVENTION

Semiconductor devices are employed in many types of equipment to perform a wide variety of applications. An important type of semiconductor device for use in the memory field is known as dynamic random access memory ("DRAM"). DRAM is extensively used for memory in computers. A basic DRAM cell may include a capacitor and a transistor formed in a semiconductor substrate. The capacitor stores a charge representing data. The transistor allows the data to be refreshed, read from, or written to the capacitor. By reducing the surface area of the capacitor or the transistor, more DRAM cells can fit onto a chip. The increase in the amount of DRAM cells results in greater memory capacity for the chip.

One method of minimizing the surface area of a DRAM cell or other memory cell is to vertically construct the components (i.e., where a semiconductor device includes components formed at several or more layers thereof). One way to accomplish such vertical construction may involve forming a trench in a semiconductor substrate. For example, polysilicon ("poly-Si") may be deposited in the trench. A recess may be created in the poly-Si by removing a portion of the poly-Si through an etching process. Layers of conductive, semiconductive and/or insulating material can then be deposited in the recessed area of the poly-Si. The steps of etching the poly-Si and depositing new material can be repeated until the desired components are formed.

A compact DRAM cell can be formed by stacking the capacitor and the transistor within the trench. For instance, the trench may be etched or otherwise formed in the substrate. The capacitor may be formed in the bottom portion of the trench. Next, an isolation material such as a trench top oxide ("TTO") may be formed over the capacitor. Adjacent to the TTO is a "buried strap." The transistor is formed on top of the TTO and the buried strap. The TTO isolates the transistor gate from the capacitor. The buried strap is the contact between the transistor and the capacitor and comprises a material such as doped polysilicon. The dopant may be arsenic, phosphorous, boron or another suitable material. The buried strap may also act as the source or drain of the transistor.

Such stacked memory devices ("vertical memory cells") can occupy less surface area compared to planar memory cells (e.g., where the transistor and capacitor are side by side) or diagonal memory cells (e.g., where the capacitor is formed in the trench and the transistor is adjacent to the surface of the trench). Thus, vertical memory cells may be placed very close together. While increasing the memory cell density, and hence increasing the memory capacity of a chip, the closeness of vertical memory cells may be problematic.

Closely spaced vertical memory cells may interfere with each other because the dopant of the buried strap tends to diffuse out into the substrate. Typically, diffusion occurs in

both vertical and horizontal directions. Vertical diffusion (e.g., diffusion in a direction parallel to the sidewalls of the trench) may improve the contact between the transistor and the capacitor of one vertical memory cell. However, when the dopant from one vertical memory cell diffuses horizontally into the substrate (e.g., diffusion in a direction perpendicular to the sidewalls of the trench), the dopant may come into contact either with the diffused dopant from a nearby vertical memory cell or a portion of the nearby cell itself. This contact may create "cross-talk" between the transistors of the nearby vertical memory cells. Cross-talk occurs when a signal from one device is inadvertently received by another device. In this situation, cross-talk may interfere with a transistor's ability to read to or write data from the capacitor to which it is attached, rendering one or both vertical memory cells nonfunctional. Therefore, there is a need for vertical memory cells having minimized buried strap horizontal out-diffusion.

SUMMARY OF THE INVENTION

The present invention provides a buried strap with reduced out-diffusion for use in stacked memory cells and a method of fabricating the buried strap.

In accordance with an embodiment of the present invention, a semiconductor device comprises a semiconductor substrate with a trench formed therein. The trench includes a sidewall. A capacitor is formed in the trench. The capacitor includes a node dielectric lining a portion of the sidewall. A buried plate is disposed in the semiconductor substrate adjacent to the node dielectric. Capacitor fill material is disposed within the trench. An insulator is disposed over at least a part of the capacitor fill material. The semiconductor device also includes a transistor, which has a source, a gate and a drain formed of a buried strap. The gate is disposed at least partly over the insulator and connects to the source. The buried strap is adjacent to the insulator and acts to connect the gate to the capacitor fill material. The buried strap includes a liner and a strap fill material. The liner reduces diffusion of the dopant in a direction substantially perpendicular to the sidewall while allowing diffusion of the dopant in a direction substantially parallel to the sidewall. Preferably, the liner is at least 22 Å thick.

In accordance with another embodiment, a semiconductor device includes a trench formed in a semiconductor substrate. The trench has a sidewall defining lower, middle and upper regions. The semiconductor device also includes a capacitor. The capacitor has a capacitor fill material comprising polysilicon and a dopant. The fill material is formed within the lower and middle regions of the trench. The semiconductor device also includes a transistor partly disposed within the upper region of the trench. An insulator is disposed on top of the capacitor. The insulator is operable to provide isolation between the capacitor and the transistor. The semiconductor device also includes a buried strap. The buried strap includes a nitride liner and a strap fill material. The buried strap is operable to function as a drain of the transistor and is operable to connect the transistor to the capacitor. The nitride liner prevents diffusion of the dopant in a direction substantially perpendicular to the sidewall. Preferably, the buried strap is formed within a divot disposed proximate to the insulator, the capacitor fill material and the sidewall.

A method of fabricating a semiconductor device of the present invention may comprise forming a trench in a semiconductor substrate, forming a collar along a sidewall of the trench, and forming a capacitor. The capacitor

includes a capacitor fill material having a dopant. The capacitor fill material is formed in a region of the trench. The collar may be recessed to form a divot, wherein a top portion of the collar is below a top surface of the capacitor fill material. A buried strap may be formed within the divot. The dopant is operable to diffuse in a direction substantially parallel to the sidewall. Preferably the liner has a first side disposed adjacent to the sidewall and a bottom connected to the first side and disposed over the top portion of the collar.

Another method of fabricating a semiconductor device of the present invention may comprise forming a trench in the semiconductor substrate. The trench has a sidewall defining lower, middle and upper regions. The method forms a node dielectric along the sidewall in the lower region of the trench. A collar is formed along the sidewall in the middle and upper regions of the trench. The lower and middle regions are substantially filled with a capacitor fill material, which comprises polysilicon and a dopant. The capacitor fill material has a top surface. A top portion of the collar is etched below the top surface of the capacitor fill material to form a divot. A nitride liner is deposited within the divot. The nitride liner has a thickness of at least about 22 Å. A strap fill material is formed within the nitride liner. The strap fill material and the nitride liner form a buried strap. The nitride liner permits diffusion of the dopant in a direction substantially parallel to the sidewall. Preferably the method includes filling the divot with a spacer after depositing the nitride liner, then etching the spacer from the divot, and removing part of the nitride liner.

In accordance with another embodiment, a semiconductor device includes a trench formed in a semiconductor substrate. The trench has a sidewall. The semiconductor device also includes a capacitor. The capacitor has a capacitor fill material comprising polysilicon and a dopant. The fill material is formed within the trench. The semiconductor device also includes a transistor at least partly disposed within the trench. An insulator is disposed on top of the capacitor. The insulator is operable to provide isolation between the capacitor and the transistor. The semiconductor device also includes a buried strap. The buried strap includes a liner and a strap fill material. The buried strap is operable to provide connectivity between the capacitor and the transistor. The semiconductor device also includes a layer of epitaxial silicon disposed on the sidewall. The layer of epitaxial silicon is adjacent to the strap fill material and the insulator. The layer of epitaxial silicon covers defects in the sidewall created during fabrication of the semiconductor device. Preferably, a gate oxide is grown on the layer of epitaxial silicon.

The semiconductor device of the present invention and the methods of fabricating a semiconductor device of the present invention provide a buried strap with reduced horizontal out-diffusion. The buried strap may be used in vertical memory cells and other semiconductor devices where diffusion can be problematic. The reduced out-diffusion permits devices to be placed closer together, thereby increasing memory capacity. The foregoing aspects, features and advantages of the present invention will be further appreciated when considered with reference to the following description of the preferred embodiments and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic cross-sectional view of a semiconductor substrate after a step in a process in accordance with an aspect of the invention.

FIGS. 2A–B are schematic cross-sectional views of a semiconductor substrate after additional steps in a process in accordance with an aspect of the invention.

FIG. 3 is a schematic cross-sectional view of a semiconductor substrate after another step in a process in accordance with an aspect of the invention.

FIGS. 4A–E are schematic cross-sectional views of a semiconductor substrate after additional steps in a process in accordance with an aspect of the invention.

FIGS. 5A–B are schematic cross-sectional views of a semiconductor substrate after additional steps in a process in accordance with an aspect of the invention.

FIGS. 6 and 6A are schematic cross-sectional views of a semiconductor substrate after additional steps in a process in accordance with an aspect of the invention.

FIGS. 7 and 7A are schematic cross-sectional views of a semiconductor substrate after additional steps in a process in accordance with an aspect of the invention.

FIG. 8 is a schematic cross-sectional view of a semiconductor substrate after another step in a process in accordance with an aspect of the invention.

FIG. 9 is a schematic cross-sectional view of a semiconductor substrate after another step in a process in accordance with an aspect of the invention.

FIGS. 10A–C are schematic cross-sectional views of a semiconductor substrate after additional steps in a process in accordance with an aspect of the invention.

FIGS. 11A–B are schematic cross-sectional views of a semiconductor substrate after additional steps in a process in accordance with an aspect of the invention.

FIG. 12 is a schematic cross-sectional view of a semiconductor substrate after another step in a process in accordance with an aspect of the invention.

FIGS. 13 and 13A are schematic cross-sectional views illustrating the result of another step in a process of forming a semiconductor device of the present invention.

DETAILED DESCRIPTION

FIG. 1 is a schematic cross-sectional illustration of a semiconductor substrate **100** at a step in a process of fabricating a vertical memory cell having direction out-diffusion in accordance with one aspect of the present invention. The substrate **100** is preferably silicon (“Si”), but various other substrates **100** may be employed, including but not limited to gallium arsenide (“GaAs”), indium phosphide (“InP”), and silicon carbide (“SiC”).

Substrate **100** has a substrate surface **102** with a pad stack **104** formed thereon. The pad stack **104** includes multiple layers of material used in later steps of fabricating a vertical memory cell. Preferably, the pad stack **104** includes a pad oxide **104a** and a pad nitride **104b**. The vertical memory cell is fabricated in a trench **106**. The trench **106** may be formed in the substrate **100** by an etching process, such as Reactive Ion Etching (“RIE”) or wet etching. The trench **106** is defined by sidewalls **108**. The sidewalls **108** may extend from the bottom of the trench **106** in a lower region A through a middle region B and an upper region C to the substrate surface **102**.

A capacitor **110** is formed in the lower region A and middle region B. The capacitor **110** preferably includes a dielectric liner **112** (commonly known as a “node dielectric”), a buried plate **114** and a capacitor fill material **116**. The node dielectric **112** is preferably disposed along the sidewalls **108** within the lower region A. The node dielectric

112 separates the two plates of the capacitor **110**. Node dielectric **112** may be, for example, an oxide, a nitride or a series of layers of oxide and nitride. One plate of the capacitor comprises a portion of the substrate **100**, and is the buried plate **114**. Buried plate **114** may be doped by ion implantation or another process. The other plate of the capacitor **110** comprises the capacitor fill material **116** disposed within the lower and middle regions A, B. The capacitor fill material **116** may be, for example, doped poly-Si or another suitable material. Preferably, the poly-Si is doped with arsenic. The capacitor fill material **116** may be formed by deposition or other well-known processes.

As shown in FIG. 1, capacitor fill material **116** has a top surface **118**. At this stage in the process of fabricating a vertical memory cell, the top surface **118** is situated at the juncture of the middle region B and upper region C. Also shown in FIG. 1 is a collar **120** that preferably lines the sidewalls **108** in the middle and upper regions B, C. The collar **120** provides isolation for a top portion of the capacitor fill material **116**, preventing parasitic leakage currents from other components from discharging the capacitor **110**. Collar **120** is preferably an oxide, which may be formed by oxidation, deposition or other processes.

FIG. 2A is a schematic cross-sectional illustration of another step of the process of fabricating a vertical memory cell, wherein the collar **120** is recessed to form a divot **130** on either side of the capacitor fill material **116** below the top surface **118**. An etching process (“divot etch”) such as RIE may create the divot **130**. The etching process may remove the collar **120** from the upper region C and part of the middle region B. By way of example only, the divot **130** may be approximately 40 nm deep by 40 nm wide.

After the divot **130** has been etched, a liner **132** is formed over the divot **130** and any exposed surfaces of the capacitor fill material **116**, pad stack **104** and sidewalls **108**, as shown in FIG. 2B. The liner **132** is preferably a nitride having a thickness of at least about 22 Å. Preferably, the liner **132** is deposited with a thickness between about 25 Å and 30 Å. Liners below about 22 Å may be unable to prevent dopant from the buried strap (discussed below) from diffusing laterally into the substrate **100**, which may cause cross-talk for closely spaced vertical memory cells. Additionally, the liner **132** preferably acts to reduce the resistance of the buried strap, which in turn may have additional benefits such as improving the speed or performance of a vertical memory cell.

After the divot **130** has been etched and the liner **132** has been deposited, the divot **130** is filled with a strap fill material. Preferably, the process of filling the divot **130** with strap fill material includes several precursor steps that will now be explained. As shown in FIG. 3, the divot **130** is initially filled with a spacer **134**, which may also coat the exposed liner **132** along the sidewalls **108** and over the pad stack **104**. The spacer **134** may be, for example, an oxide. The spacer **134** may be formed by a chemical vapor deposition (“CVD”) process such as low pressure CVD (“LPCVD”). In an example, the spacer **134** is between approximately 10 nm and 40 nm thick. In another example, the spacer **134** is at least 20 nm thick.

As shown in FIG. 4A, the spacer **134** is preferably removed from the liner **132** covering the top surface **118** and the top of the pad stack **104**. The spacer **134** may be removed by RIE or another etching process. Removing the spacer **134** in this manner preferably exposes the nitride liner **132** on horizontal surfaces.

Then, as shown in FIGS. 4B and 4C, the same or a different etching process is continued to “overetch” the

spacer **134**, thereby removing the liner **132** covering the top surface **118** and the top of the pad stack **104**. Preferably, this etching process employs a wet etch that is selective to nitride (e.g., where nitride is removed more quickly than other materials are removed). The “overetch” preferably removes a portion of the spacer **134** and the liner **132** at the interface between the spacer **134** and the capacitor fill material **116**. As shown in FIG. 4C, the liner **132** at the interface is partly removed, although the liner **132** may be totally removed from the vertical interface between the spacer **134** and the capacitor fill material **116**. Removing the liner **132** in this manner preferably acts to reduce the buried strap resistance.

Continuing the etching process, FIGS. 4D and 4E illustrate the trench **106** wherein the spacer **134** is preferably completely removed from the sidewalls **108** (that are covered by the liner **132**). As shown in FIG. 4E, the liner **132** has been recessed below the top surface **118**.

FIG. 5A illustrates another step in the process of forming a vertical memory cell, wherein strap fill material **140** is formed within the divot **130**, along the sidewalls **108** lined with the liner **132**, and over the top surface **108** and the pad stack **104**. The strap fill material **140** is preferably poly-Si, although other semiconductive materials such as silicon germanium (“SiGe”) may be used. Optionally, the strap fill material **140** is doped. The dopant may be arsenic, phosphorous, boron or another suitable material. In situ doping, diffusion, soaking or other suitable processes may be employed to add the dopant to the poly-Si. With in situ doping, the dopant and poly-Si are preferably obtained from gasses that are flowed together over the divot **130**. In diffusion, the poly-Si is preferably first deposited within the divot **130**, and then exposed to a gas containing the dopant at a selected temperature and pressure. Soaking preferably requires deposition of the poly-Si, followed by exposing the poly-Si to the dopant until a coating of a few atomic layers covers the poly-Si. Then the dopant is diffused into the poly-Si by annealing.

The strap fill material **140** is partially removed after formation. As shown in FIG. 5B, the strap fill material **140** is preferably removed from the pad stack **104**, the top surface **118**, and along the sidewalls **108** lined with the liner **132**. The strap fill material may be removed through an etching process as described above. The strap fill material preferably remains in the divot **130**. Optionally, a polysilicon film may be grown over the strap fill material **140** and the top surface **118**, preferably by an epitaxial silicon growth process. The epitaxial silicon growth process is preferably performed at a pressure of between approximately 0.05 Torr to 1 Torr. The temperature is preferably within the range of about 500° C. to 850° C. Growing the polysilicon film preferably increases the thickness of the strap fill material **140** and decreases buried strap resistance. The liner **132** acts to prevent growth of polysilicon on the sidewalls **108**.

After the strap fill material **140** is formed within the divot **130**, an insulator such as a TTO is formed over the divot **130** and the top surface **118** of the capacitor fill material **116**. In one embodiment, the insulator is deposited within the trench **106** (as will be explained later in relation to FIG. 12).

In another embodiment, the insulator is preferably formed according to the following steps. A first TTO **142** is deposited as shown in FIG. 6. Preferably, the first TTO **142** covers the pad stack **104**, the top surface **118** of the capacitor fill material **116**, and the strap fill material **140**. FIG. 6A provides a magnified view of the first TTO **142**.

Then the liner **132** is preferably removed from the sidewalls **108** in the upper region C, as shown in FIGS. 7 and

7A. The liner **132** preferably remains along the entire exterior surface and bottom surface of the divot **130**, and partly along the inner surface of the divot **130** adjacent to the capacitor fill material **116**. As will be described in relation to FIG. **13A**, the structure of the liner **132** preferably permits out-diffusion of the dopant through the strap fill material **140** in a direction substantially parallel to the sidewalls **108** but reduces out-diffusion in a direction substantially perpendicular to the sidewalls **108**, such that cross-talk with a nearby semiconductor device may be eliminated.

FIG. **8** illustrates another step in the process of forming a vertical memory cell, wherein epitaxial Si ("epi-Si") **150** is grown on the exposed trench sidewalls **108** in upper region C. The epi-Si **150** preferably extends from the first TTO **142** to the top of the upper region C. It is desirable to grow the epi-Si **150** because the sidewalls **108** may have defects or may have become damaged or uneven during earlier processing steps. The epi-Si preferably provides a defect-free surface on which a high quality gate oxide may be grown. The epi-Si **150** is also beneficial because it provides a region for the dopant from the capacitor fill material **116** to diffuse into, as will be explained later in relation to FIG. **13**. By way of example only, the epi-Si **150** is formed having a thickness between approximately 300 Å and 400 Å. The epi-Si **150** is preferably nitridized, leaving a coating of silicon nitride ("SiN") **152** over the epi-Si **150**. The SiN coating **152** acts to protect the epi-Si **150** during further steps of fabricating a vertical memory cell.

In an aspect of the invention shown in FIG. **9**, the first TTO **142** is completely removed by, for instance, wet etching. Completely removing the first TTO **142** preferably results in a recess **180** beneath the epi-Si **150** and SiN coating **152**.

In another aspect of the invention, the first TTO **142** is partially etched by, for example, RIE. FIG. **10A** illustrates such a partial etch, wherein a portion of the first TTO **142** beneath the epi-Si **150** remains. Then, the remainder of the first TTO **142** is removed by another etching process, such as wet etching as shown in FIGS. **10B–C** to form the recess **180**. The two-step removal of first TTO **142** according to FIGS. **10A–B** can minimize the etching of other structures (e.g., the strap fill material **140** and the capacitor fill material **116**) within the trench **106**.

Regardless of the process used to remove the first TTO **142**, additional fill material **154** is then deposited in the recess **180** and over the strap fill material **140**. Preferably, the additional fill material **154** comprises the same material as the strap fill material **140**. As shown in FIG. **11A**, the additional fill material **154** may be deposited over exposed surfaces within the trench **106** and on top of the pad stack **104**. As shown in FIG. **11B**, the additional fill material **154** is preferably etched so that it remains only along the liner **132** and on top of at least part of the strap fill material **140**. The SiN coating **152** is preferably removed after this etching process. A sacrificial layer **156** is formed along the exposed surfaces of the trench **106**, including the epi-Si **150**, the top surface **118**, the strap fill material **140** and the additional fill material **154**. Preferably, the sacrificial layer **156** is an oxide.

FIG. **12** illustrates another step in the process of forming a vertical memory cell, wherein an insulator **160** (e.g., TTO) is deposited or otherwise formed within the trench **106** along the bottom of the upper region C. The insulator **160** preferably covers the sacrificial layer **156** that is on the top surface **118** of the capacitor fill material **116**, the strap fill material **140**, and any additional fill material **154**.

The process of forming a vertical memory cell preferably continues as shown in FIG. **13**, wherein the sacrificial layer

156 is preferably removed from the epi-Si **150**. A gate oxide **170** may be grown on the epi-Si **150**. Then a final fill material **172** is deposited or otherwise formed in the remainder of the trench **106**, covering the insulator **160** and the gate oxide **170**. The final fill material **172** is preferably arsenic doped poly-Si, and may have the same composition and structure as the capacitor fill material **116**.

As shown in the enlarged view of FIG. **13A**, dopant from the capacitor fill material **116** is permitted to diffuse along a path D. The path D may be affected by the thickness and structure of the liner **132**. The path D preferably provides dopant diffusion in a direction substantially parallel to the sidewall **108**, while minimizing diffusion in a direction perpendicular to the sidewall **108**. The dopant may diffuse through the buried strap and into the epi-Si **150** as part of the path D. Returning to FIG. **13**, after the gate oxide **170** is grown and the final fill material **172** is deposited, further processing steps may then be performed to complete formation of a vertical memory cell.

One advantage of the present invention is the semiconductor device includes a buried strap providing reduced horizontal out-diffusion. The reduced out-diffusion minimizes the possibility for cross-talk between nearby semiconductor devices. Another advantage of the present invention is that the thickness of the liner reduces the resistance of the buried strap. Yet another advantage of the present invention is the growth of epi-Si on exposed trench sidewalls. The epi-Si provides a relatively defect-free surface on which the gate oxide is grown. A further advantage of the epi-Si is that it provides a region for the dopant to diffuse into from the capacitor fill material. The buried strap, liner and epi-Si may be used in structures other than trench memory cells, including planar memory cells and other semiconductor devices.

Although the invention herein has been described with reference to particular embodiments, it is to be understood that these embodiments are merely illustrative of the principles and applications of the present invention. It is therefore to be understood that numerous modifications may be made to the illustrative embodiments and that other arrangements may be devised without departing from the spirit and scope of the present invention as defined by the appended claims.

What is claimed is:

1. A semiconductor device comprising:

- a trench formed in a semiconductor substrate, the trench having a sidewall;
- a capacitor, the capacitor having a node dielectric lining a portion of the sidewall, a buried plate disposed in the semiconductor substrate adjacent to the node dielectric, and capacitor fill material including a dopant, the capacitor fill material being disposed within the trench;
- an insulator, disposed over at least a part of the capacitor fill material; and
- a transistor, the transistor having a source, a gate disposed at least partly over the insulator and connected to the source, and a buried strap adjacent to the insulator and the capacitor fill material, the buried strap including a liner and a strap fill material, wherein the buried strap acts as a drain of the transistor and the liner has a first side disposed between the sidewall and the strap fill material and reduces diffusion of the dopant in a direction substantially perpendicular to the sidewall while allowing diffusion of the dopant in a direction substantially parallel to the sidewall.

2. The semiconductor device of claim 1, wherein the liner is at least about 22 Å thick.

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3. The semiconductor device of claim 2, wherein the liner is between about 25 Å–30 Å thick.

4. The semiconductor device of claim 1, wherein the liner comprises a nitride.

5. A semiconductor device comprising:

a trench formed in a semiconductor substrate, the trench having a sidewall;

a capacitor, the capacitor having a node dielectric lining a portion of the sidewall, a buried plate disposed in the semiconductor substrate adjacent to the node dielectric, and capacitor fill material including a dopant, the capacitor fill material being disposed within the trench;

an insulator disposed over at least a part of the capacitor fill material; and

a transistor, the transistor having a source, a gate disposed at least partly over the insulator and connected to the source, and a buried strap adjacent to the insulator and the capacitor fill material, the buried strap including a liner and a strap fill material, wherein the liner has a first side disposed adjacent to the sidewall and a bottom disposed adjacent to the first side, and the strap fill material is partly surrounded by the first side and the bottom, and wherein the buried strap acts as a drain of the transistor and the liner reduces diffusion of the dopant in a direction substantially perpendicular to the sidewall while allowing diffusion of the dopant in a direction substantially parallel to the sidewall.

6. The semiconductor device of claim 5, wherein the transistor is disposed in middle and upper regions of the trench, and the first side of the liner extends from the base into the upper region.

7. The semiconductor device of claim 5, wherein the liner further includes a second side disposed between the strap fill material and the capacitor fill material.

8. A semiconductor device comprising:

a trench formed in a semiconductor substrate, the trench having a side all defining lower, middle and upper regions;

a capacitor including a capacitor fill material comprising polysilicon and a dopant, the capacitor fill material being formed within the lower and middle regions of the trench;

a transistor partly disposed within the upper region of the trench;

an insulator disposed on top of the capacitor, the insulator being operable to provide isolation between the capacitor and the transistor; and

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a buried strap, the buried strap including a nitride liner and a strap fill material, wherein the buried strap is operable to function as a drain of the transistor and is operable to connect the transistor to the capacitor, and the nitride liner has a first side disposed between the sidewall and the strap fill material and prevents diffusion of the dopant in a direction substantially perpendicular to the sidewall while allowing diffusion of the dopant in a direction substantially parallel to the sidewall.

9. The semiconductor device of claim 8, wherein the buried strap is formed within a divot disposed proximate to the insulator, the capacitor fill material and the sidewall.

10. The semiconductor device of claim 9, further comprising a layer of epitaxial silicon disposed on the sidewall in the upper region of the trench, the layer of epitaxial silicon being disposed adjacent to the strap fill material.

11. The semiconductor device of claim 8, wherein the strap fill material comprises polysilicon.

12. A semiconductor device comprising:

a trench formed in a semiconductor substrate, the trench having a sidewall;

a capacitor including a capacitor fill material comprising polysilicon and a dopant, the capacitor fill material being formed within the trench;

a transistor at least partly disposed within the upper region of the trench;

an insulator disposed on top of the capacitor, the insulator being operable to provide isolation between the capacitor and the transistor;

a buried strap including a liner and a strap fill material, the buried strap being operable to provide connectivity between the capacitor and the transistor; and

a layer of epitaxial silicon disposed on the sidewall, the layer of epitaxial silicon being adjacent to the strap fill material and the insulator, wherein the layer of epitaxial silicon covers defects in the sidewall created during fabrication of the semiconductor device.

13. The semiconductor device of claim 12, further including a gate oxide disposed on the layer of epitaxial silicon.

14. The semiconductor device of claim 13, wherein the gate oxide is grown on the layer of epitaxial silicon.

15. The semiconductor device of claim 12, wherein the layer of epitaxial silicon is between 300 Å and 400 Å thick.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 6,768,155 B2
DATED : July 27, 2004
INVENTOR(S) : Venkatachalam C. Jaiprakash and Rajiv Ranade

Page 1 of 1

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 9,
Line 38, "side all" should read -- sidewall --.

Signed and Sealed this

Eleventh Day of January, 2005

A handwritten signature in black ink that reads "Jon W. Dudas". The signature is written in a cursive style with a large, looped initial "J".

JON W. DUDAS
Director of the United States Patent and Trademark Office